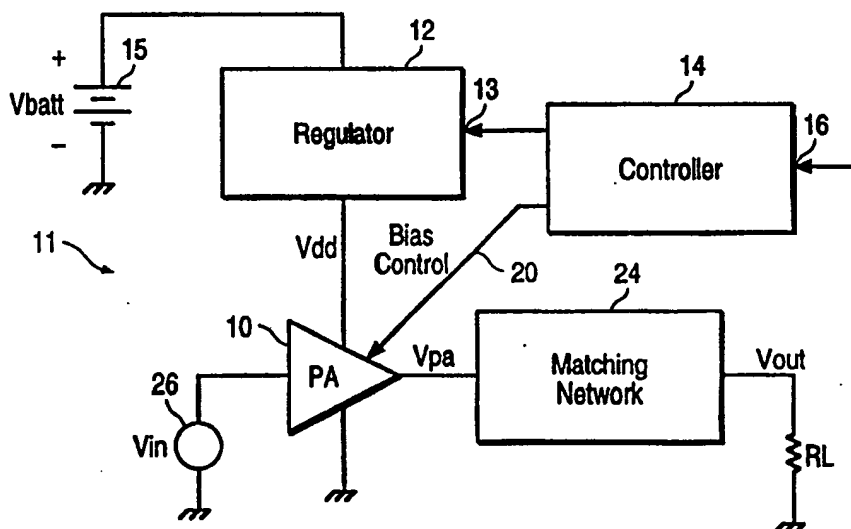




## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

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(21) International Application Number: <b>PCT/US98/06870</b> (22) International Filing Date: <b>8 April 1998 (08.04.98)</b> (30) Priority Data: 08/843,107                      25 April 1997 (25.04.97)                      US (71) Applicant: <b>TRIQUINT SEMICONDUCTOR, INC. [US/US];</b> 2300 N.E. Brookwood Parkway, Hillsboro, OR 97124 (US). (72) Inventors: <b>SHARP, Steven; 221 N.W. Miller, Portland, OR</b> <b>97229 (US). TAYLOR, Stewart, S.; 16927 N.W. Hazel-</b> <b>grove Court, Beaverton, OR 97006 (US). HAMMOND,</b> <b>Samuel, W.; 14150 S.W. Allen Boulevard #60, Beaver-</b> <b>ton, OR 97005 (US). RUEBUSCH, Ronald, R.; 5635 S.W.</b> <b>Knightsbridge Drive, Portland, OR 97219 (US).</b> (74) Agent: <b>OGONOWSKY, Brian; Skjerven, Morrill, MacPherson,</b> <b>Franklin &amp; Friel LLP, Suite 700, 25 Metro Drive, San Jose,</b> <b>CA 95110 (US).</b>	(81) Designated States: <b>BR, CA, CN, IL, JP, KR, SG, European</b> <b>patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR,</b> <b>IE, IT, LU, MC, NL, PT, SE).</b>  Published <i>With international search report.</i> <i>With amended claims.</i>	

(54) Title: BATTERY LIFE EXTENDING TECHNIQUE FOR MOBILE WIRELESS APPLICATIONS



## (57) Abstract

An operating voltage applied to a transmitter's power amplifier in a mobile wireless transceiver is dynamically controlled so as to improve the efficiency of the transmitter at all output power levels. In one embodiment, the bias current levels within the transmitter are also varied to optimize the efficiency of the transmitter at all output power levels. In a preferred embodiment, a highly efficient switching regulator is controlled by a control circuit to adjust the operating voltage and/or bias current for the power amplifier in the transmitter. The control circuit has as its input any of a variety of signals which reflect the actual output power of the transmitter, the desired output power, or the output voltage swing of the transmitter.

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BATTERY LIFE EXTENDING TECHNIQUE FOR  
MOBILE WIRELESS APPLICATIONS

5

10

FIELD OF THE INVENTION

This invention relates to wireless transmitters and, in particular, to a technique for extending the battery life in such a transmitter.

15

BACKGROUND

Extending battery life is a key concern for users and manufacturers of cellular telephones and other portable transceivers. A powerful signal generated and transmitted by the wireless transceiver draws more power from the battery than when a lower power signal is generated and transmitted. Accordingly, a number of prior art techniques have been employed to adjust the gain of a portable transmitter so as to not transmit a signal more powerful than necessary for adequate communications. Examples of such ways of automatically adjusting the output power level of a transmitter are described in U.S. Patent Nos. 4,760,347, 5,129,098, and 5,446,756, incorporated herein by reference.

Although the prior art techniques selectively reduce the output power of the transmitter, the efficiency of the transmitter is not improved by the prior art methods. The transmitter is typically biased, and operating voltages are set, so that the transmitter output signal will not distort in an adverse way at the highest expected output signals. These worse case operating conditions can draw

significant power from the battery even when no signal is being transmitted. Such worst case operating conditions are not required when the transmitter is not transmitting its maximum signal. Hence, the  
5 transmitter's efficiency is lower when transmitting lower power output signals. A lower efficiency equates to wasting battery power, reducing talk time.

What is needed is a technique for extending the battery life in mobile wireless applications.

10

#### SUMMARY

A technique is described herein which dynamically reduces the operating voltage applied to a transmitter's power amplifier in a mobile wireless  
15 transceiver so as to increase the efficiency of the transmitter when the transmitter is not outputting its maximum output power. Thus, the total power consumption of the transmitter is reduced as compared to prior art transmitters. In another embodiment, the  
20 bias voltage or bias current levels within the transmitter are also varied to optimize the efficiency of the transmitter at a particular output power level. This technique of controlling the transmitter's operating voltage and bias voltage/current may be used  
25 in conjunction with conventional techniques for automatically reducing the gain of the transmitter.

In a preferred embodiment, a highly efficient switching regulator is controlled by a control circuit to adjust the operating voltage and bias  
30 voltage/current for the power amplifier in the transmitter. The control circuit has as its input any of a variety of signals which reflect the actual output of the transmitter or the desired output power of the transmitter.

35

### BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a block diagram of the basic components of a transmitter section in a wireless transceiver incorporating one embodiment of the present invention.

5 Figs. 2-6 illustrate various embodiments of controllers for controlling an output of a voltage regulator for application to a power amplifier in a wireless transceiver.

10 Fig. 7 illustrates one embodiment of a controller for controlling an output voltage of a voltage regulator for application to a receiver in a wireless transceiver.

Figs. 8 and 9 illustrate a conventional buck type regulator and a boost type regulator, respectively.

15 Fig. 10 illustrates one embodiment of a power amplifier which has its efficiency improved using the present invention.

### DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

20 Fig. 1 illustrates a power amplifier 10 for a transmitter 11 whose operating voltage  $V_{dd}$  is provided by a variable voltage regulator 12. The output voltage  $V_{dd}$  of regulator 12 is controlled by a signal from a controller 14 applied to a control terminal 13. A  
25 battery 15 supplies power to regulator 12.

Controller 14 receives a signal at an input terminal 16 which signifies the actual output power of the power amplifier 10, the desired output power of amplifier 10, or a measure of the output voltage swing  
30 of amplifier 10. Controller 14 then sets, based on this input signal, the output voltage  $V_{dd}$  of regulator 12 such that amplifier 10 will operate under its most efficient conditions for the particular output power level.

35 Controller 14 also, optionally, provides a bias voltage or bias current control signal to amplifier 10

via line 20 to adjust the bias current or voltage levels in amplifier 10 for optimum efficiency at a particular output power level.

When amplifier 10 is outputting its maximum power level, the output voltage  $V_{pa}$  swing of amplifier 10 is a maximum, and amplifier 10 operates with relatively high efficiency. The various transistors and other components in amplifier 10 are biased and otherwise operated so as not to introduce significant distortion into the output signal. As the output power is reduced, the output voltage swing and current drawn from battery 15 are reduced. In accordance with one embodiment of the invention, because of the reduced output voltage swing, the operating voltage  $V_{dd}$  provided to amplifier 10 by regulator 12 is reduced, without introducing distortion, to save additional power.

Further, in accordance with one embodiment of the invention, as the power output level is reduced, the bias voltages and currents are also reduced, without introducing distortion, to save additional power.

Power consumption is the product of the RMS voltage and current drawn from battery 15. Hence, by reducing the RMS voltage to amplifier 10, power consumption is reduced beyond that provided by prior art power consumption techniques. Because cellular telephones generally operate at less than full power most of time, using the invention shown in Fig. 1 will extend the life of battery 15 significantly.

A matching network 24 (e.g., a resonant circuit) interfaces the output of amplifier 10 to a load  $RL$ . Load  $RL$  may be an antenna or other load. An input signal generator 26 generates a modulated RF signal  $V_{in}$  in a conventional way and may include automatic gain control circuitry.

Figs. 2-6 illustrate some of the techniques which may be used by controller 14 to detect the output power or desired output power of amplifier 10 in order to suitably control regulator 12 to generate a variable V<sub>dd</sub> for amplifier 10 or to control the bias settings in amplifier 10.

In Fig. 2, a power detector 30 is connected to the output of power amplifier 10 or to the output of the matching network 24, via a coupler 31, to generate a voltage at lead 32 related to the output power of amplifier 10. Coupler 31 couples a small percentage of the output signal to the power detector 30. Power detectors are well known and may take many forms. Controller 42 converts the signal on lead 32 into a control signal for regulator 12 for adjusting V<sub>dd</sub> to optimize the efficiency of amplifier 10.

Controller 42 may be coupled to a feedback terminal 43 of regulator 12, where the feedback signal V<sub>fb</sub> has a predetermined relationship with the voltage on lead 32. Thus, controller 42 may simply be a level shifter or suitable amplifier. By appropriate design of the power detector 30, the feedback terminal 43 of regulator 12 may instead be directly connected to lead 32, so that the power detector 30 acts as the controller. The relationship between the input of controller 42 and the output of controller 42 is to be determined based upon the particular regulator 12 and power amplifier 10 used.

Some cellular telephones and other wireless transceivers already employ an output power detector for another purpose, and, thus, the present invention may be easily incorporated into such devices.

Regulator 12 may be any conventional high-efficiency switching regulator which provides an output voltage based upon a feedback signal, as is well-known in the art. In conventional voltage regulator

circuits, the feedback terminal of a regulator is connected to a divided regulated output voltage.

Fig. 3 illustrates a controller 50 which senses the output voltage  $V_{pa}$  of amplifier 10 and essentially acts as a negative peak detector to output a voltage  $V_{np}$  representative of the most negative output of amplifier 10 over a period of time. The battery voltage  $V_{batt}$  applied to terminal 52 slowly pulls up node 54 to the battery voltage through resistor 56. Voltages applied to the cathode of diode 58 which are lower than one diode drop below the voltage at node 54 pull down the voltage at node 54 to approximately the most negative voltage applied to terminal 52 plus a diode drop. The selection of the resistor 56 value and the capacitor 59 value determines the response of controller 50. The RC time constant is preferably set so that there is no appreciable change at node 54 from cycle to cycle.

The voltage at node 54 is applied to one input terminal of an amplifier 60, and a reference voltage 62 is applied to another input terminal. The output of amplifier 60 is applied to the feedback terminal of regulator 12. In response, regulator 12 provides an operating voltage  $V_{dd}$  to amplifier 10 so as to maintain the voltage at node 54 at approximately  $V_{ref}$ . If  $V_{ref}$  is held fixed, then controller 50 acts to regulate the minimum voltage across the amplifier 10 output transistor(s) needed to avoid adverse distortion, thus optimizing the amplifier's efficiency at all output power levels. The technique of Fig. 3 may be used to control the minimum voltage across the transistors in all stages of amplifier 10 (e.g., transistors Q1 and Q2 in Fig. 10). For example, with reference to Fig. 10, the minimum drain-source voltage across transistors Q1 and Q2 to allow transistors Q1 and Q2 to operate in a linear region is regulated using the circuit of Fig. 3.



A buffer may be needed between the output of amplifier 10 and the input of controller 50 to avoid undue loading.

Fig. 4 illustrates a controller 70 for regulator 12 which receives as its input a receive signal strength indication (RSSI), provided by a conventional RSSI circuit 72 which generates a voltage indicating the strength of a received signal. The strength of the received signal is, in certain cases, indicative of the required power to be transmitted for adequate two-way communication. This is especially true when the remote originating transmit power is known. The wireless transceiver may already contain a RSSI circuit 72 for a different purpose. A higher RSSI signal thus indicates to controller 70 to provide a feedback signal to regulator 12 to lower the voltage  $V_{dd}$  to amplifier 10 to improve the efficiency of amplifier 10 at the lower output power.

Fig. 5 illustrates how an input into controller 76 may be the baseband signal 78 which is mixed with the modulating RF carrier, generated by modulator 80, by multiplier 82. Since the output power of amplifier 10 varies with the amplitude of the baseband signal 78, controller 76 may cause regulator 12 to modulate the voltage  $V_{dd}$  into amplifier 10 in accordance with the baseband signal. The technique of Fig. 5 is only applicable for forms of modulation which have non-constant envelopes.

In another embodiment, shown in Fig. 6, controller 83 receives its signal directly from the output of amplifier 10 or the matching network 24. Controller 83 converts this signal level into a control signal for regulator 12.

Other forms of controllers would be suitable depending upon the specific transmitter to be controlled.

Fig. 7 illustrates a receiver 85 in a wireless transceiver which receives its operating voltage Vdd from regulator 12. Controller 87 controls the output of regulator 12 to improve the efficiency of receiver 85 at lower received signal levels. A lower strength received signal, detected by RSSI circuit 72, lowers the Vdd applied to receiver 85 to optimize efficiency. Bias voltage/current levels may also be adjusted by controller 87 via line 88.

Figs. 8 and 9 illustrate two types of simple switching regulators: Fig. 8 illustrates a buck type regulator 90, and Fig. 9 illustrates a boost type regulator 92. Such regulators may be used for regulator 12 in the various figures. In such regulators, the duty cycle of the switch S1 (typically a switching transistor) is controlled, where the duty cycle is directly proportional to the output voltage Vdd of the regulator. A duty cycle controller 94 controls the switching of S1 based upon a feedback signal Vfb from any of the controllers shown in Figs. 1-7. A reference voltage Vref is compared to the feedback signal by amplifier 96 for adjusting the duty cycle of switch S1. An oscillator 98 provides the switching frequency of switch S1. Those skilled in the art are familiar with the operations of the regulators of Figs. 8 and 9. A boost-buck regulator may also be used, which is typically a combination of the circuits of Figs. 8 and 9.

Fig. 10 illustrates one of the many appropriate types of power amplifiers 10 which may be used with the present invention. A modulated RF input signal from generator 26 is supplied through resistor R and capacitor C1 to the input of a field effect transistor Q1. A variable bias voltage generator 106, controlled by controller 14 in Fig. 1, provides a bias voltage for operating transistor Q1 around a certain operating

point. Inductor L1 and capacitor C1 form an input matching network for transistor Q1. The signal generated at the drain of transistor Q1 is provided to the gate of transistor Q2, via DC blocking capacitor C2, for further amplification. Inductor L2, inductor L3, and capacitor C2 form a matching network between transistors Q1 and Q2.

The drain of transistor Q2 provides the output  $V_{pa}$  of amplifier 10. A second variable bias voltage generator 108, controlled by controller 14 in Fig. 1, provides a bias voltage for operating transistor Q2 around a certain operating point. The drain of transistor Q2 is connected to a matching network 24 for appropriate resonant tuning to improve gain, lower the return loss, lower distortion, increase output power, and increase efficiency. The matching network 24 consists of inductor L4 connected between  $V_{dd2}$  and transistor Q2, inductor L5, and capacitors C3 and C4. The voltage output  $V_{out}$  is then applied across a load  $R_L$  (e.g., an antenna) for transmission.

The operating conditions of transistors Q1 and Q2 must be set so that the voltage swings and/or drain currents of transistors Q1 and Q2 are not distorted in an unacceptable way. The adjustable bias voltages  $V_{bias1}$  and  $V_{bias2}$  as well as voltages  $V_{dd1}$  and  $V_{dd2}$  are therefore dynamically controlled to avoid such distortion of the signals provided by transistors Q1 and Q2. Suitably controlling the operating conditions using the present invention results in less battery power being wasted through the various conduction paths.

The variable voltage sources (e.g., controllable regulators) used for sources 106 and 108 may be conventional. The particular bias voltages needed at various output power levels are determined on a case-

by-case basis depending upon the particular amplifier and application.

The controller 14 (Fig. 1) may control the output of regulator 12 to set the Vdd1 and Vdd2 levels to be  
5 the same or different, depending on the minimum voltage needed to operate transistors Q1 and Q2 at low distortion at a particular output power.

In the example shown in Fig. 10, transistors Q1 and Q2 are metal-semiconductor field effect transistors  
10 (MESFETs).

A power amplifier using bipolar technology may also utilize the present invention, where the collector-emitter voltage Vce of the amplifier's transistor(s) is regulated to be a minimum needed to  
15 operate the transistor(s) at all output levels without distortion. Such an amplifier may replace the MESFET transistors Q1 and Q2 in Fig. 10 with bipolar transistors. MOSFET transistors may also be used.

This technique of dynamically adjusting the  
20 operating conditions in an amplifier may be applied to many forms of power amplifiers, and the particular type of controller used will depend upon the method which will provide the most efficient use of battery power at a reasonable cost. Many of the circuits which generate  
25 the input to controller 14 (Fig. 1) already exist in certain cellular telephones, such as the power detection circuit 30 of Fig. 2 and the RSSI circuit 72 of Fig. 4. The present invention is not restricted to any particular switching regulator (e.g., PWM, PFM),  
30 and a suitable regulator may also be a non-switching regulator, such as a linear regulator. However, switching regulators are known to be highly efficient.

It is expected that the present invention will increase the battery life of cellular telephones and  
35 other wireless transceivers by as much as 50% or more. In some applications, it is anticipated that battery

life will be at least doubled using the present invention.

While particular embodiments of the present invention have been shown and described, it will be  
5 obvious to those skilled in the art that changes and modifications may be made without departing from this invention in its broader aspects and, therefore, the appended claims are to encompass within their scope all  
10 such changes and modifications as fall within the true spirit and scope of this invention.

CLAIMS

What is claimed is:

- 1... A mobile wireless device comprising:  
an amplifier connected to receive an input  
5 signal to be transmitted, said amplifier having a  
power supply input terminal and an amplifier  
output terminal;  
a controllable voltage regulator having a  
10 battery input terminal and a voltage control  
terminal, said regulator having an output voltage  
terminal connected to said power supply input  
terminal of said amplifier; and  
a controller having an output connected to  
15 said control terminal of said regulator and a  
controller input terminal connected to receive a  
signal related to an output level at said  
amplifier output terminal.
2. The device of Claim 1 wherein said regulator  
20 controls a voltage across one or more transistors in  
said amplifier.
3. The device of Claim 2 wherein said one or  
more transistors are MOSFET transistors, and said  
25 regulator controls a drain-source voltage of said one  
or more transistors.
4. The device of Claim 2 wherein said one or  
more transistors are MESFET transistors, and said  
30 regulator controls a drain-source voltage of said one  
or more transistors.
5. The device of Claim 2 wherein said one or  
more transistor are bipolar transistors, and said  
35 regulator controls a collector-emitter voltage of said  
one or more transistors.

6. The device of Claim 2 wherein said one or more transistors in said amplifier include one or more output transistors of said amplifier.

5 7. The device of Claim 1 wherein said regulator is controlled to output a voltage based upon an actual output level at said amplifier output terminal.

10 8. The device of Claim 1 wherein said controller and said regulator maintain a minimum output voltage at said amplifier output terminal at a predetermined level.

15 9. The device of Claim 1 wherein said controller comprises a power detector connected to receive said signal related to an output level at said amplifier output terminal.

20 10. The device of Claim 1 further comprising a matching network connected between said amplifier output terminal and a load.

25 11. The device of Claim 10 wherein said load is an antenna.

12. The device of Claim 1 wherein said controller comprises a minimum voltage detector.

30 13. The device of Claim 1 further comprising a baseband signal generator, wherein said controller receives a baseband signal and controls said regulator in response to said baseband signal.

35 14. The device of Claim 1 wherein said controller input terminal is connected to said amplifier output terminal.

15. The device of Claim 1 further comprising a matching network connected between said amplifier output terminal and an antenna, wherein said controller input terminal is connected to an output of said matching network.

16. The device of Claim 1 further comprising a receive signal strength indicator, wherein said controller input terminal receives a signal corresponding to an output of said receive signal strength indicator.

17. The device of Claim 1 wherein said regulator is a switching regulator.

18. The device of Claim 1 wherein said control terminal of said regulator is a feedback terminal.

19. The device of Claim 1 wherein said regulator controls bias currents within said amplifier.

20. A method for controlling a wireless device comprising:

amplifying a signal for transmission;  
generating a control signal based upon an output level of said amplifier; and  
controlling a voltage output of a voltage regulator by said control signal, said regulator providing voltage to operate said amplifier.

21. The method of Claim 20 wherein said regulator provides voltage to a power supply terminal of said amplifier.

22. The method of Claim 20 wherein said regulator controls an operating point of one or more transistors



in said amplifier to improve efficiency in said amplifier.

23. The method of Claim 20 wherein said regulator  
5 controls a voltage across one or more transistors in  
said amplifier to improve efficiency in said amplifier.

24. The method of Claim 23 wherein said regulator  
controls a drain-source voltage of one or more MOSFET  
10 transistors in said amplifier.

25. The method of Claim 23 wherein said regulator  
controls a drain-source voltage of one or more MESFET  
transistors in said amplifier.

15

26. The method of Claim 23 wherein said regulator  
controls a collector-emitter voltage of one or more  
bipolar transistors in said amplifier.

## AMENDED CLAIMS

[received by the International Bureau on 06 October 1998 (06.10.98);  
original claims 7,9,13 and 14 cancelled; original claims 1,15 and 20 amended;  
remaining claims unchanged (5 pages)]

an amplifier connected to receive an input  
signal to be transmitted, said amplifier having a  
power supply input terminal and an amplifier  
5 output terminal;

a controllable voltage regulator having a  
battery input terminal and a voltage control  
terminal, said regulator having an output voltage  
terminal connected to said power supply input  
10 terminal of said amplifier;

a receive portion that receives a signal from  
another transmitting device and generates a signal  
strength indication signal indicative of the  
strength of said signal received by said another  
15 transmitting device; and

a controller having an output connected to  
said control terminal of said regulator and a  
controller input terminal connected to receive a  
signal related to said signal strength indication  
20 signal to cause an average power output of said  
amplifier to be related to said signal strength  
indication signal.

2. The device of Claim 1 wherein said regulator  
25 controls a voltage across one or more transistors in  
said amplifier.

3. The device of Claim 2 wherein said one or  
more transistors are MOSFET transistors, and said

regulator controls a drain-source voltage of said one or more transistors.

4. The device of Claim 2 wherein said one or  
5 more transistors are MESFET transistors, and said regulator controls a drain-source voltage of said one or more transistors.

5. The device of Claim 2 wherein said one or  
10 more transistor are bipolar transistors, and said regulator controls a collector-emitter voltage of said one or more transistors.

6. The device of Claim 2 wherein said one or  
15 more transistors in said amplifier include one or more output transistors of said amplifier.

8. The device of Claim 1 wherein said controller and said regulator maintain a minimum output voltage at  
20 said amplifier output terminal at a predetermined level.

10. The device of Claim 1 further comprising a matching network connected between said amplifier  
25 output terminal and a load.

11. The device of Claim 10 wherein said load is an antenna.

12. The device of Claim 1 wherein said controller comprises a minimum voltage detector.

15 15. The device of Claim 1 further comprising a matching network connected between said amplifier output terminal and an antenna.

16. The device of Claim 1 further comprising a receive signal strength indicator, wherein said  
10 controller input terminal receives a signal corresponding to an output of said receive signal strength indicator.

17. The device of Claim 1 wherein said regulator  
15 is a switching regulator.

18. The device of Claim 1 wherein said control terminal of said regulator is a feedback terminal.

20 19. The device of Claim 1 wherein said regulator controls bias currents within said amplifier.

20. A method for controlling a wireless device comprising:

25           amplifying a signal for transmission;  
              receiving a signal from another transmitting device;  
              generating a signal strength indication  
              signal indicative of the strength of said signal  
30           received from said another transmitting device;

generating a control signal based upon said  
signal strength indication signal; and

controlling a voltage output of a voltage  
regulator by said control signal, said regulator  
5 providing voltage to operate said amplifier,

said step of generating a control signal  
controlling said amplifier such that an average  
power output of said amplifier is related to said  
signal strength indication signal.

10

21. The method of Claim 20 wherein said regulator  
provides voltage to a power supply terminal of said  
amplifier.

15

22. The method of Claim 20 wherein said regulator  
controls an operating point of one or more transistors  
in said amplifier to improve efficiency in said  
amplifier.

20

23. The method of Claim 20 wherein said regulator  
controls a voltage across one or more transistors in  
said amplifier to improve efficiency in said amplifier.

25

24. The method of Claim 23 wherein said regulator  
controls a drain-source voltage of one or more MOSFET  
transistors in said amplifier.

30

25. The method of Claim 23 wherein said regulator  
controls a drain-source voltage of one or more MESFET  
transistors in said amplifier.

26. The method of Claim 23 wherein said regulator controls a collector-emitter voltage of one or more bipolar transistors in said amplifier.

5

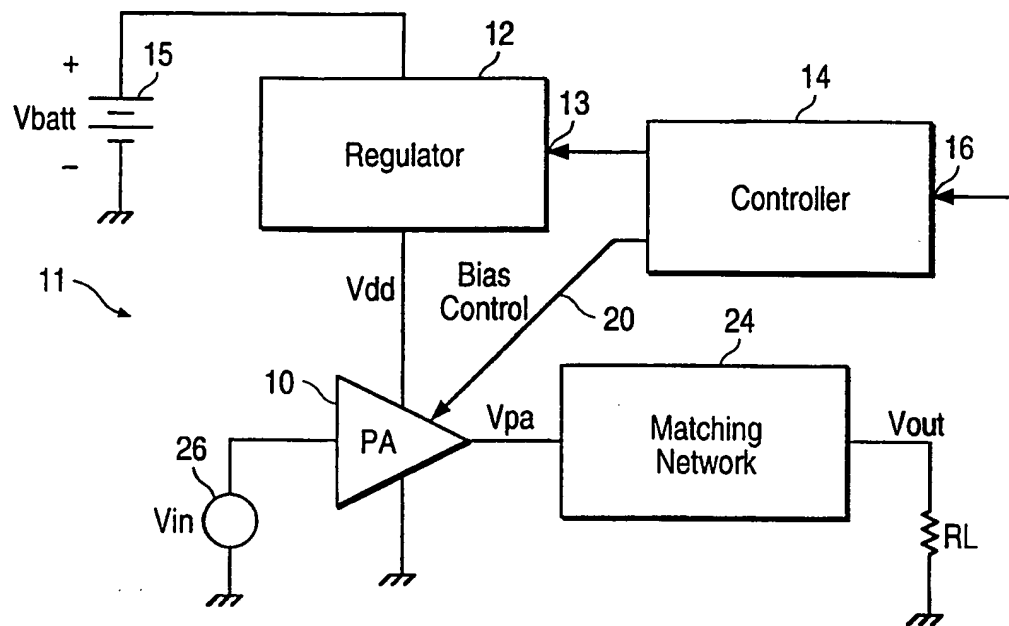


FIG. 1

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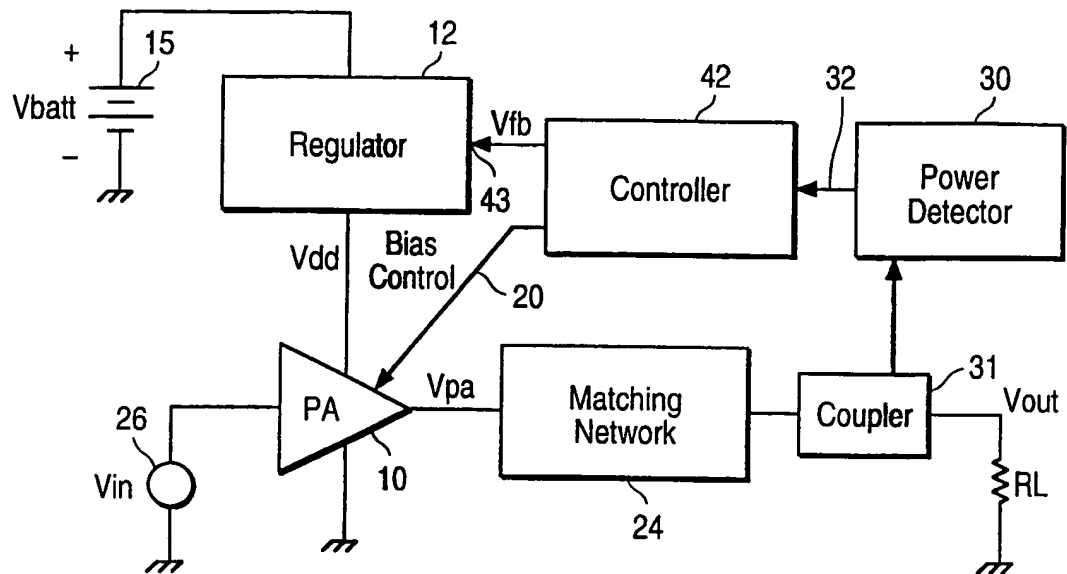


FIG. 2

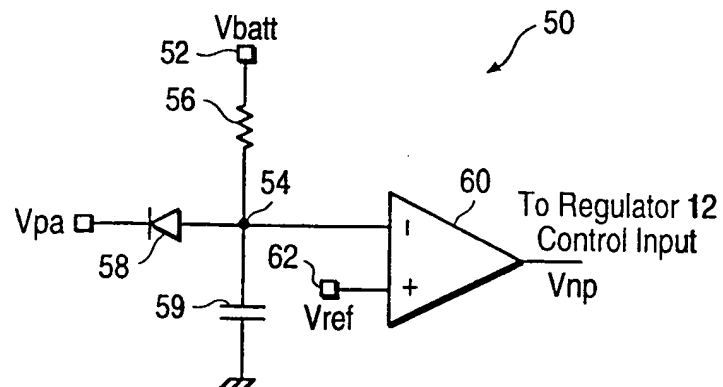


FIG. 3



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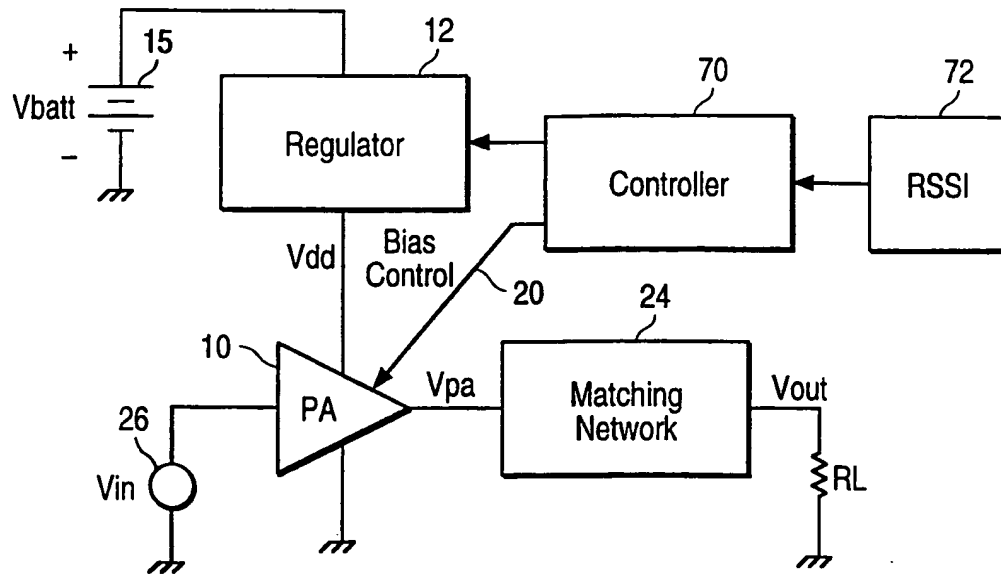


FIG. 4

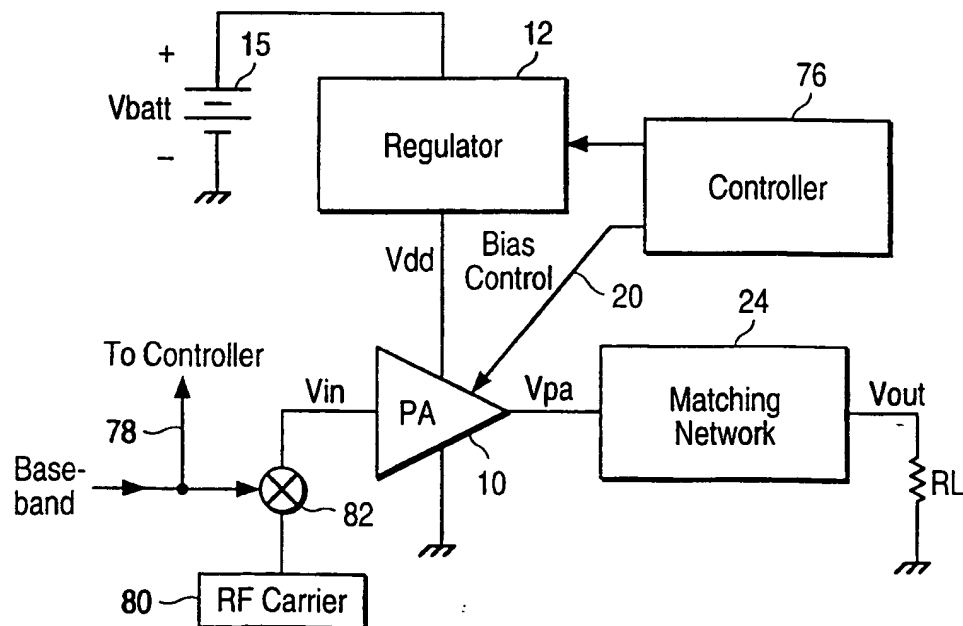


FIG. 5

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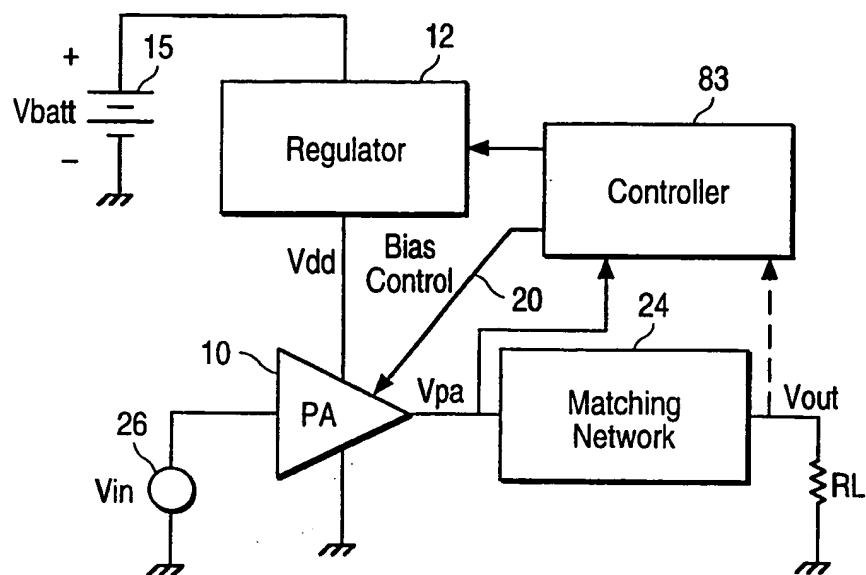


FIG. 6

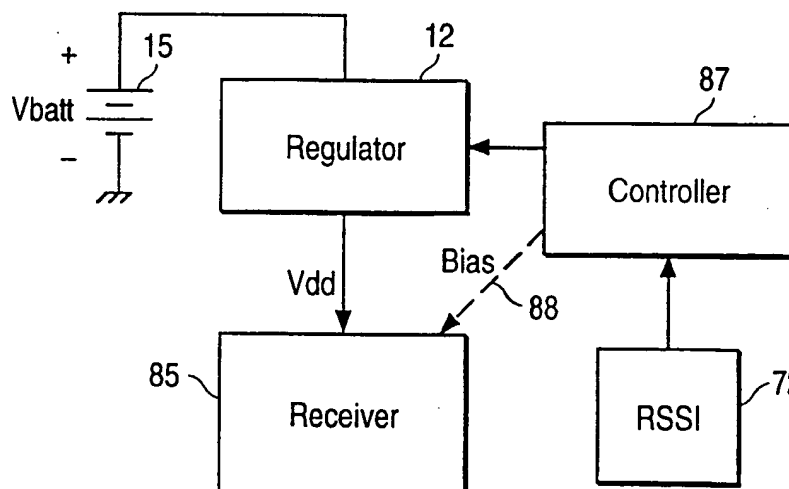


FIG. 7

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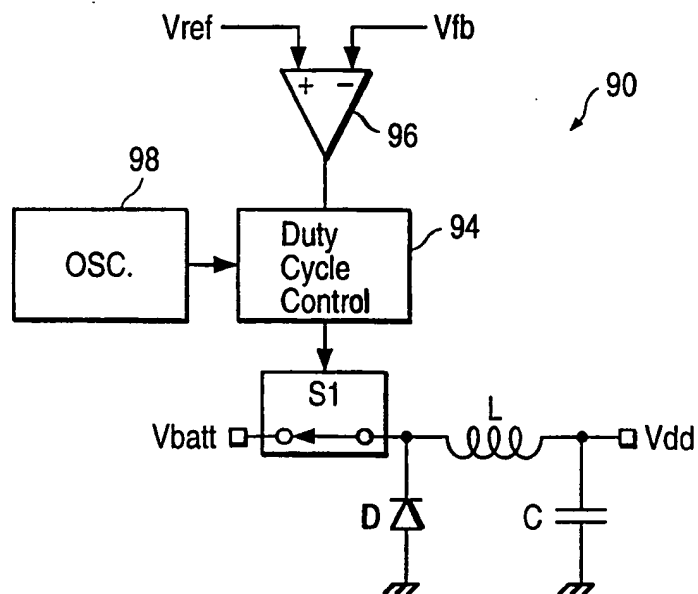


FIG. 8  
(PRIOR ART)

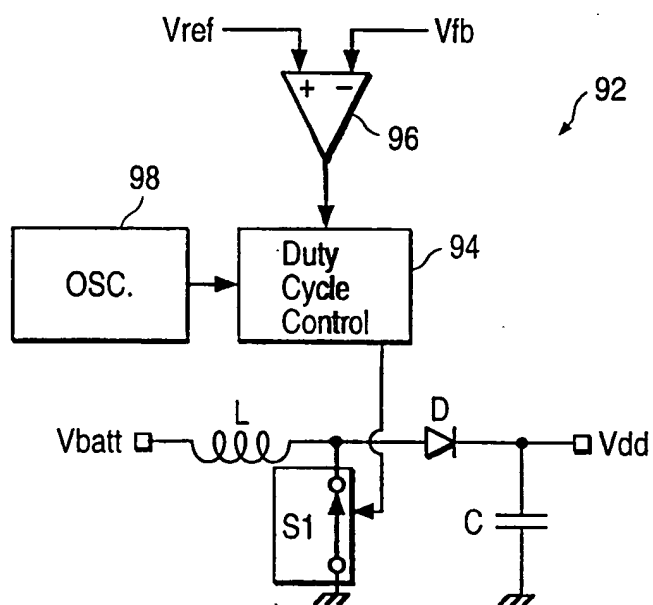


FIG. 9  
(PRIOR ART)

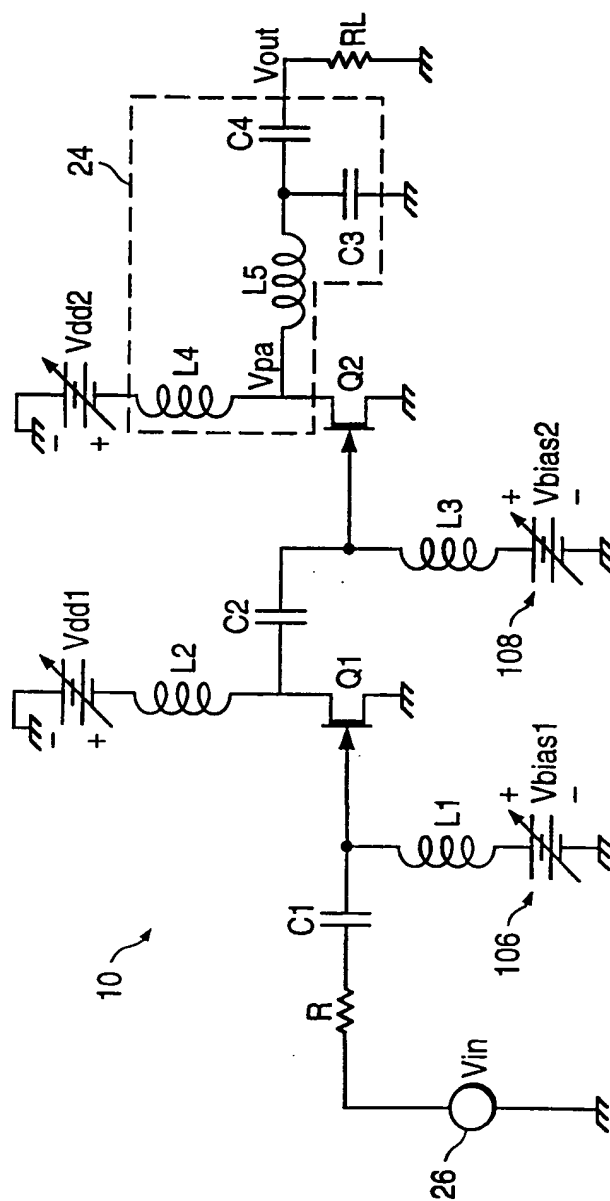


FIG. 10

# INTERNATIONAL SEARCH REPORT

International Application No  
PCT/US 98/06870

**A. CLASSIFICATION OF SUBJECT MATTER**  
IPC 6 H03G3/30

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)  
IPC 6 H03G

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 182 527 A (NAKANISHI EIICHI ET AL) 26 January 1993  see column 5, line 39 - column 8, line 47 see column 9, line 47 - line 64; figures 1,3,6-8	1-6, 8-12,17, 19-26
X	WO 96 33555 A (QUALCOMM INC) 24 October 1996 see page 6, line 3 - line 8 see page 9, line 18 - line 38; figures 2,10	1,7,14, 20
X	US 4 994 757 A (BICKLEY ROBERT H ET AL) 19 February 1991 see the whole document	1,20

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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Date of the actual completion of the international search

26 June 1998

Date of mailing of the international search report

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Name and mailing address of the ISA

European Patent Office, P.B. 5818 Patentlaan 2  
NL - 2280 HV Rijswijk  
Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,  
Fax: (+31-70) 340-3016

Authorized officer

Blaas, D-L

# INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/US 98/06870

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